

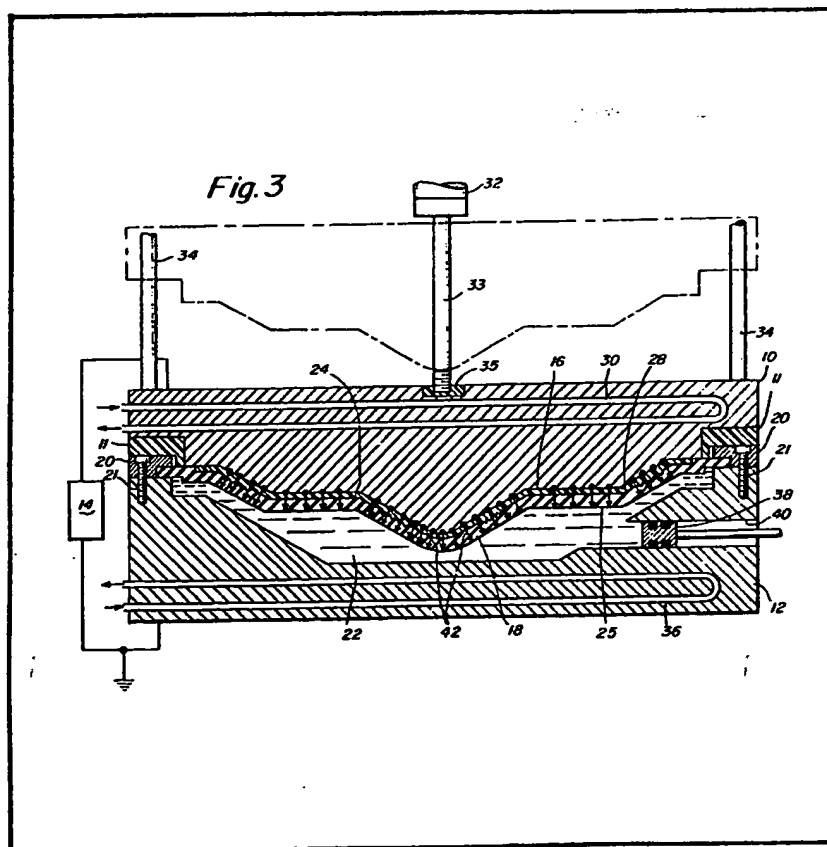
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(54) Compression Moulding

(57) In a molding process and apparatus for making plastics parts utilizing a radio frequency heating field and means for applying constant pressure, two metallic mold halves (10, 12) are joined clamping therebetween an imprinted diaphragm (18) having the plastics on one side thereof between the diaphragm and one of the mold halves and a liquid conductor, such as mercury (22), or a

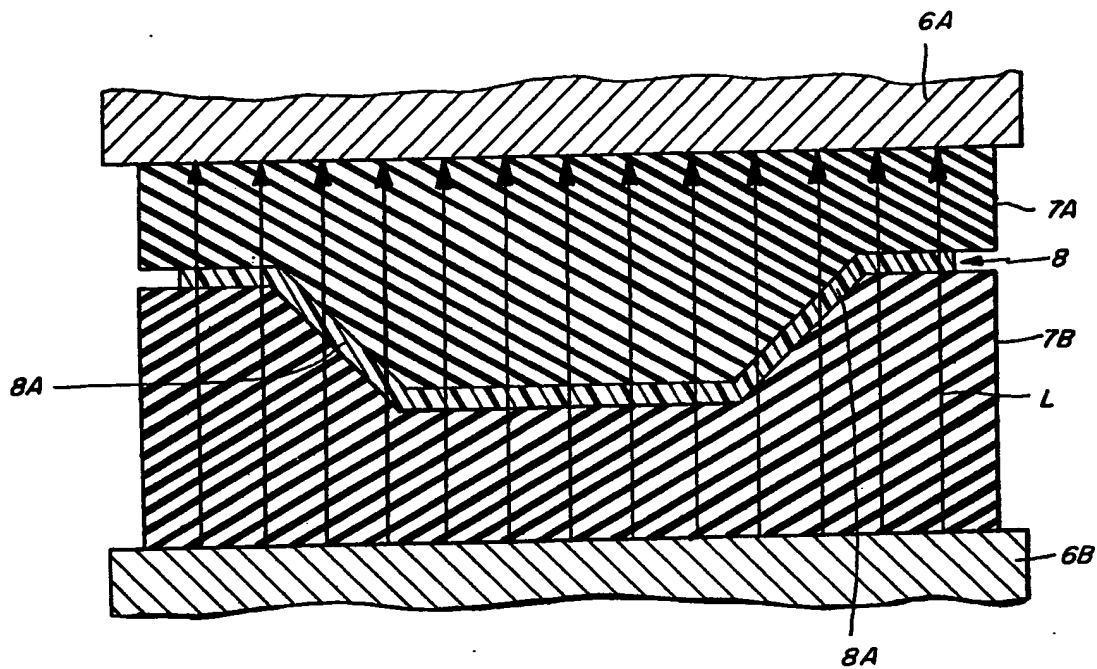
sodium or graphite solution fills a space on the other side of the diaphragm. Each of the mold halves is provided with means for cooling (30, 36). After the plastics material, which may be in liquid, powder or sheet form, is in place and the mold is closed, the field is applied, and the mercury is pressurised. In another embodiment the material is compressed between one electrode platen and a resilient pad on a second electrode platen.



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PRIOR ART

Fig. 1

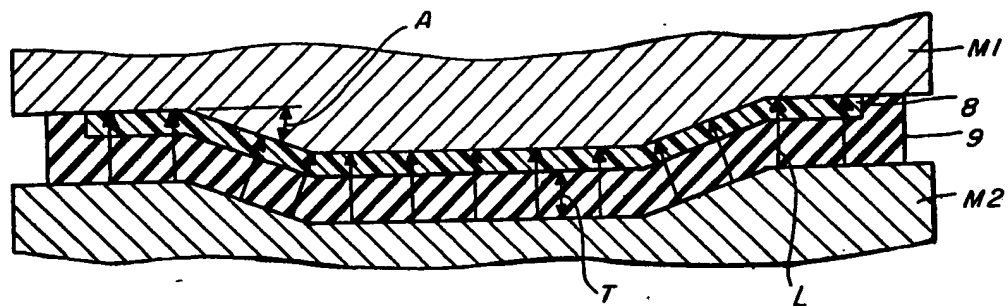


Fig. 2

Fig. 3

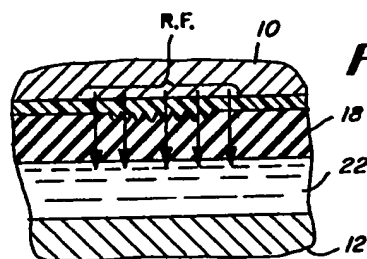
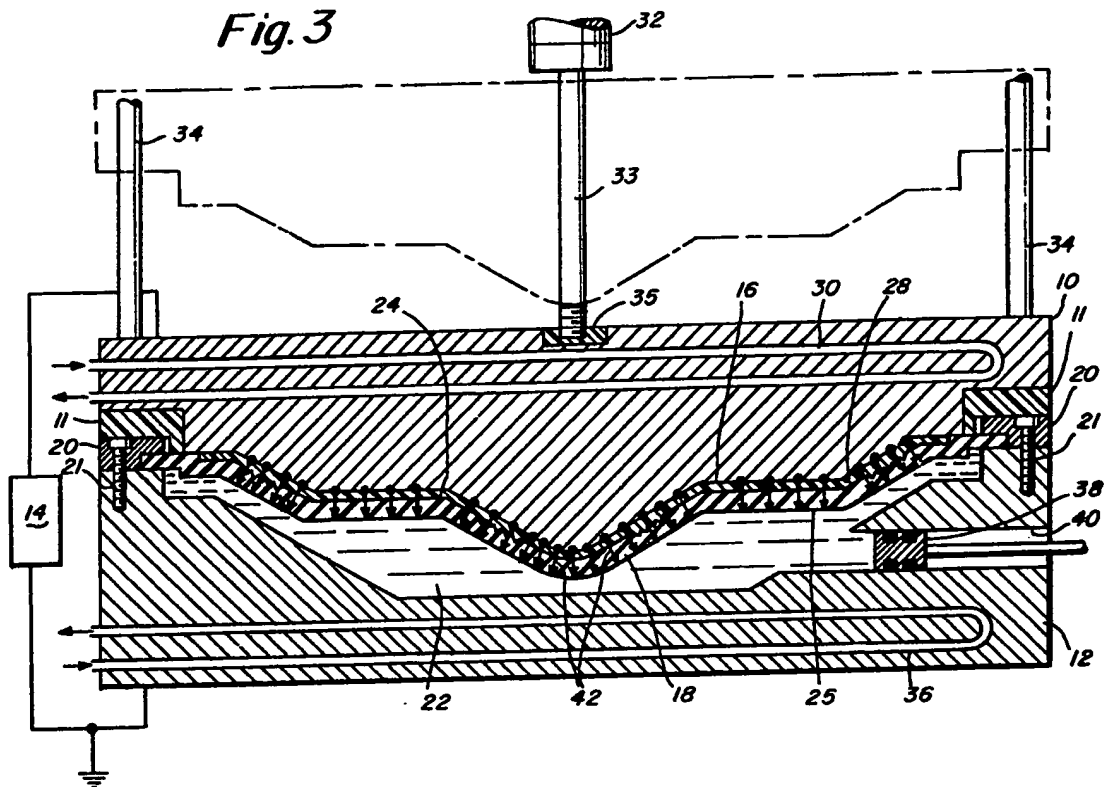
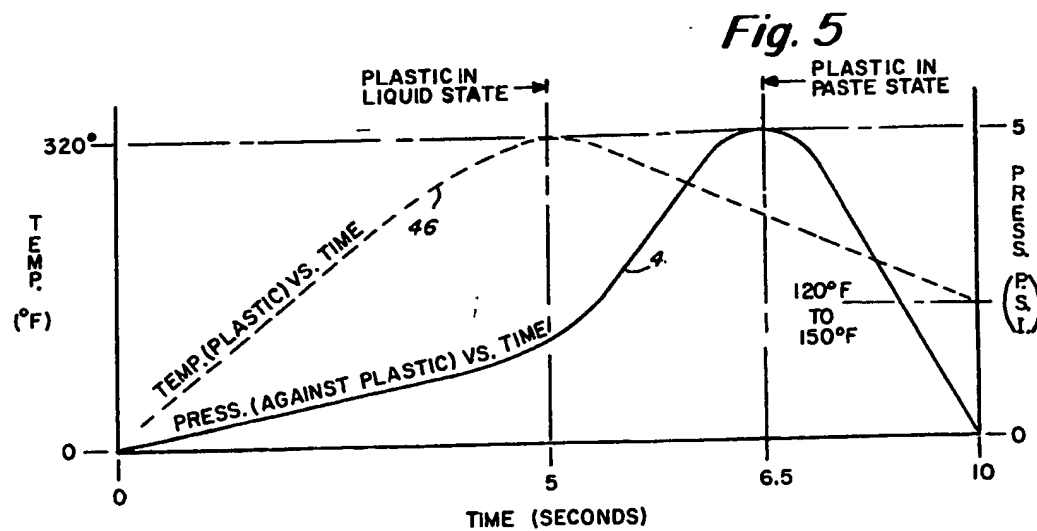


Fig. 4



SPECIFICATION **Flow Molding**

The present invention relates in general to a flow molding process and associated apparatus.

5 More particularly, the invention pertains to the flow molding of either two-dimensional or three-dimensional parts or items constructed of plastic or the like material. The techniques of this invention may be used in constructing parts for use in many different fields such as in the automotive industry in, for example, the manufacture of decorative interior plastic parts.

10 The conventional molding technique for plastic parts involves a heating of the mold cavity in combination with a closing of the mold cavity to compress the plastic into the desired configuration. The known techniques, such as shown in Figure 1 of this application as discussed in more detail hereinafter, are adequate in constructing some parts or items, however, these techniques are generally only useful in constructing substantially planar pieces hereinafter termed two-dimensional pieces. By two-dimensional pieces, we are not referring to pieces that have no third dimension but are referring to pieces that either have a very small third dimension or pieces that depart in their construction, only a slight amount from a planar configuration. In the molding of three-dimensional pieces, and especially those requiring an accurate imprinting, these traditional techniques are not adequate, as it has been found that the plastic tends to burn in some areas and yet remain cold and thus not flow in other areas. This occurs because the heat gradient is not uniform at the plastic surface at all points therealong. A plastic piece such as shown in the illustration of Figure 3 is considered as a three-dimensional part and the usual prior art technique in constructing this part is to convert a two-dimensional part into the three-dimensional part by reheating and stretching and bending the part over a mandrel. However, this technique results in a loss of distortion of the grain or pattern of the part and, in addition, internal stresses are produced which may cause material fatigue and a loss of shape of the item.

In the prior art, the plastic is compressed by virtue of the interacting motion between the mold halves. However, this tends to create an unequal pressure gradient on the plastic when considering three-dimensional parts such as shown in the illustration of Figure 3, discussed hereinafter.

15 In view of these prior art disadvantages, it is an object of the present invention to provide an improved flow molding technique, particularly useful for molding three-dimensional parts wherein a uniform temperature gradient may be established across the part to prevent any burning or cold spots in the final part.

Another object of the present invention is to provide an improved flow molding technique particularly useful for molding three-dimensional parts and wherein the plastic has applied thereto,

65 substantially equal pressure along all surfaces thereof assuring a good imprint from the mold along with the application of an equal temperature gradient throughout the plastic material which assures an even flow of the material.

70 Another object of the present invention is to provide a flow molding process and associated apparatus wherein the molds are of simple and inexpensive construction especially in comparison to injection molding apparatus.

75 A further object of the present invention is to provide a flow molding technique employing a high radio frequency field for heating primarily the plastic within the mold and which is characterized by a reduced cool down time and a reduced amount of energy consumption.

To accomplish the foregoing and other objects of this invention there is provided a flow molding apparatus, preferably for constructing three-dimensional pieces. The apparatus comprises a mold having a cavity therein for receiving a material which may be a plastic in liquid, powder or sheet form possibly backed with cloth or leather and which is to be finally formed into a finished piece. A diaphragm is disposed in the cavity having the plastic material or the like on one side thereof for forming at least one surface of the piece. This diaphragm is preferably made from a master having the desired imprint along one surface thereof. In a preferred version of the invention wherein it is desired to provide both a uniform temperature gradient and a uniform pressure, the apparatus also comprises a compressible fluid means which is preferably a liquid conductor such as mercury. This fluid means is disposed in the cavity for compressing the other side of the diaphragm. A fluid pressurizing or compressing means is used such as a piston arrangement to apply pressure to the liquid conductor. Finally, means are provided for establishing an electromagnetic heating field across the mold.

100 With the above described apparatus the proper temperature and pressure gradients are established at the surface of the plastic material. The contact line between the liquid conductor and the diaphragm preferably has the same contour as the imprinted surface of the diaphragm and this contact line has the same potential therealong.

105 Similarly, the contact line between the top electrode (mold half) and the plastic material matches the contour of the plastic material to also provide the same potential therealong. Thus, as will be evident in the disclosed embodiment discussed in detail hereinafter, the current (ampere) field lines are perpendicular to the plastic surface at all points thus providing a uniform temperature throughout the plastic.

120 Furthermore, with the use of a compressible fluid means on one side of the diaphragm equal pressure is applied to the diaphragm which is preferably a silicone rubber diaphragm which in turn applies even pressure to the plastic surface at all points allowing a perfect imprint in the plastic

As mentioned above, the preferred technique of this invention provides for both uniform compression and a uniform temperature gradient. However, in the manufacture of some parts, and in particular those that depart only slightly from a planar, two-dimensional shape, such as shown in Figure 2, the compression is provided by a closing of the mold halves in combination with the application of a uniform temperature gradient which is possible by providing matching surfaces of the diaphragm wherein the diaphragm has a constant and uniform thickness all along the plastic part so that the temperature lines are substantially perpendicular to the plastic part at all points therealong thus providing the uniform temperature gradient.

Numerous other objects, features and advantages of the invention should become apparent upon a reading of the following detailed description taken in conjunction with the accompanying drawings, in which:

Figure 1 is a schematic prior art view of the known molding technique;

Figure 2 is a schematic diagram of a mold construction in accordance with the present invention;

Figure 3 is a cross-sectional view taken through an apparatus of the present invention showing the mold in its clamped closed position with the further inclusion of a compressible fluid for providing uniform pressure at the part;

Figure 4 is an enlarged cross-sectional view of a segment of the structure shown in Figure 3; and

Figure 5 is a pressure-temperature diagram associated with the method and apparatus of this invention.

Figure 1 is a prior art schematic diagram depicting the mold halves 6A and 6B which carry respectively the silicone rubber diaphragm 7A and 7B defining a mold cavity for the plastic part 8. The entire mold construction is not shown in Figure 1 because the diagram of Figure 1 is merely schematic. It is noted in Figure 1 that the mold halves or electrodes 6A and 6B establish a field across the dielectric material of diaphragms 7A and 7B. The field lines L provide uniform heating only along the horizontal portions of the plastic part 8. Along the two slanted portions of part 8 there is a tendency for the field to overheat the plastic and cause burning spots in those areas. Also, the compression is provided by closing the electrodes 6A and 6B and thus there is also a nonuniform pressure gradient in particular along the slanted portions 8A of the plastic part 8.

In Figure 1 it is also noted that the diaphragm 7A and 7B have a non-uniform thickness thereby causing the lines L to all run vertically as depicted in Figure 1.

Figure 2 on the other hand is a schematic diagram of one of the simple versions of the present invention providing a uniform temperature gradient along the entire plastic part 8. In Figure 2 the construction comprises mold halves M1 and M2. In this arrangement two

diaphragms could be used. However, only one diaphragm 9 is illustrated in Figure 2 carried by the bottom mold half or electrode M2. The top mold half M1 has a surface facing the plastic part 8 that is to match the desired configuration of the part 8. Thus, the mold half M1 itself forms one surface of the mold cavity.

The diaphragm 9 shown in Figure 2 has a uniform thickness T along the length of the plastic part 8. Thus, the energy heating lines L are not all vertical but instead are all substantially perpendicular to the surface of the plastic material that is to be formed. In this way an even temperature gradient is established all along the plastic part.

The technique of Figure 2 may be used in constructing plastic parts that depart only slightly from a planar configuration. For example, in constructing the part shown in Figure 1 it would be preferred to use a method as discussed hereinafter with reference to Figure 3. However, with the technique of Figure 2, parts can be constructed wherein any angle of deviation such as the angle A shown in Figure 2 is in the range of 0°—20°. For angles greater than 20°, the technique of Figure 3 is preferred. Also, where the surface requires a good imprint from the mold, it also desired to use the technique of Figure 3.

In Figure 3 there are shown mold halves 10 and 12 which are also referred to, respectively, as top and bottom electrodes. An electromagnetic energy source 14 is shown coupling to these electrodes for establishing a potential difference therebetween. Between the electrodes there is formed a cavity 16 in which is disposed the rubber diaphragm 18 secured at either end by insulating clamps 20. The bottom electrode 12 is constructed with a reservoir for receiving a compressible, preferably conductive, liquid shown in Figure 1 as mercury 22.

The rubber diaphragm 18 has an imprinted surface 24 and may be constructed of a silicone rubber material. The diaphragm may be made from a master using any one of a number of different known techniques. The master, of course, corresponds, in shape and contour to the plastic part that is going to be fabricated with the apparatus of Figure 1. Also, the top electrode has its surface 28 machined or cast to fit the inside (non-grain) surface of the master. Both of the electrodes 10 and 12 may be constructed of an aluminum material. The top electrode has passages 30 for permitting the passage of a coolant such as water or Freon (Registered Trade Mark). An actuating cylinder 32 connects by rod 33 to the top electrode 10 enabling this electrode to separate from the bottom electrode to either load the plastic material or remove the cured plastic from the mold. Figure 1 also shows a pair of guides 34 that are used for properly aligning the two electrodes.

The material that is to be formed by the process of this invention may be in a liquid, powder or sheet form and may be draped in the cavity 16 or injected into the cavity 16 from

outside of the mold with the use of one or more passages through the mold but not shown in Figure 1. If sheets of plastic are used the sheets may be rigid or flexible and may be backed with another material such as cloth or leather.

The bottom electrode 12 is also provided with a cooling passage 36. In addition, this electrode is machined with a relatively deep cavity allowing a relatively substantial space for the mercury 22.

Figure 2 shows a piston assembly 38 slideable within passage 40 of the electrode 12 for selectively exerting pressure on the mercury which is in turn uniformly coupled to the surface of the diaphragm 18.

The electrodes and the diaphragm are preferably constructed so that the contour lines or surfaces 28, 16 and 25 essentially match each other in a substantially parallel surface arrangement. Also, the liquid in the reservoir of the bottom electrode is preferably conductive so as to establish current lines 42 which are substantially perpendicular to the plastic part at all points therealong as clearly depicted in Figure 1. In other words, the same potential exists at the surface 28 all therealong and also uniform but different potential exists all along the surface 25 of the diaphragm. Because of this current line distribution there will be uniform heating all along the plastic piece providing an extremely uniform flow therealong. In addition, the diaphragm 18 is somewhat flexible and with the use of a compressible liquid which is compressible by piston assembly 38, it is possible to provide a totally uniform pressure on the surface 25 of the diaphragm; which pressure is conveyed to the plastic part to provide an excellent imprint in the plastic part as it is desired. In accordance with the process of the present invention the mold may be operated by means of the cylinder 32 to either separate the mold or clamp the mold together. Figure 1 shows the mold in a clamped and closed position wherein the diaphragm 18 has been secured at its end by clamps 20. The mold halves or electrodes 10 and 12 are also appropriately secured together in any well known manner. Prior to closing the mold, the plastic is introduced into the cavity 16 either in liquid, powder or sheet form. When the mold is closed the mercury is already in place in the position shown in Figure 1 but the piston assembly 38 is withdrawn sufficiently so that there is little or no pressure exerted on the diaphragm by the mercury at an initial stage of the process.

When the mold is securely closed, the source 14 is selectively operates to apply electromagnetic energy across the electrodes causing a uniform heating through the plastic material. In this connection reference is now made to the graphs of Figure 3 which show two waveforms including a waveform 46 of temperature versus time and a waveform 48 of pressure versus time. The temperature that is recorded may be the temperature of the plastic material sensed by a thermocouple not shown in the drawings. The pressure is the pressure

measured in the cavity.

In accordance with one process, the heat that is generated from the electromagnetic field is applied for a period of 5 seconds with the plastic material in the mold thereby being in a liquid state by virtue of this applied heat. The pressure exerted by the assembly 38 is maintained for this 5 second interval and also for an additional 5 second interval. The pressure exerted by the piston assembly 38 is controlled by a relatively low, gradually increasing pressure during the first 5 second interval as depicted in Figure 3 with the pressure thereafter increasing and peaking, for example, at the 6.5 second time point. The pressure exerted by assembly 38 follows a curve substantially the same as the curve 48 shown in Figure 3.

The silicone rubber diaphragm 18 may have a thickness on the order of 1/4 to 3/8 of an inch. Because this diaphragm is quite flexible, the pressure in the cavity quite closely follows the pressure waveform imposed by the piston assembly 38.

It has been found that the use of a liquid form of plastic is preferred. One such product that has been used is Plasticsol.

Although mercury has been disclosed as one type of liquid conductor that is used with the invention, it is understood that other liquids including liquids in paste form may be used in place of the mercury. In fact, it may be more advantageous to use a sodium or graphite solution because mercury vapors are poisonous. Even though the mold is closed the silicone rubber diaphragm is somewhat more porous and there is a possibility that the mercury vapors may escape from the mold. Another liquid conductor that may be used is a fusible alloy which is maintainable in a liquid state at about 120°F. The liquid may be an alloy of bismuth, lead, tin, or cadmium.

When fusible alloys are used instead of the liquid mercury it is preferred that the mold be maintained, as previously indicated, at a temperature on the order of 120°F. Thus, the water that is passed through the passages 36 may be maintained at a temperature of, for example, 150°F. This water is still sufficient to cool the plastic. The top mold may be maintained at ambient temperature.

As viewed from the top, the mold may have a square or rectangular shape with the clamp 20 extending about the perimeter of the mold. The clamp 20 firmly fastens the rubber diaphragm into the bottom mold half 12 by means of the screws 21 shown in Figure 1. Figure 1 also shows the rod 33 which couples from the cylinder 32 being electrically insulated by member 35. This insulation member is necessary if the rod 33 is grounded to the frame of the machine in any way. Because a potential is being applied to the mold half 10 it is of course, necessary to isolate any grounded members such as even the guides 34.

The cylinder 32 and its associated rod 33 provide for the opening and closing of the mold

and also function as a clamping means after the mold is closed. The cylinder 32 has a bore size that is large enough with the air pressure that is applied to create a downward force greater than the force created by the pressure of the fluid conductor on the diaphragm. To limit the downward position of the top mold half 10 there is provided a stop member 11 which is an electrical insulator that is preferably secured to the mold half 10. The stop member 11 limits the motion between the mold halves. The member 11 is constructed of an insulator material because there is a voltage applied to the mold half 10 and its potential must be insulated from all grounded points. The cylinder 32 may also have associated therewith a toggle mechanism for maintaining it in its locked or clamped position.

The method apparatus of Figure 3 is also particularly useful in constructing plastic parts having one or more reverse curves. In the past, these parts could not be readily constructed with a molding process because of the difficulty of separating the mold after the part is manufactured. However, with the technique of Figure 3 after the part has been constructed, a vacuum reverse pressure can be applied to cause a slight opening of the rubber diaphragm thereby permitting each separation between the mold halves.

Having described one embodiment of the present invention it should now be apparent to those skilled in the art that numerous other embodiments are contemplated as falling within the scope of this invention which is to be defined by the appended claims.

Claims

1. Flow molding apparatus comprising; means defining a mold having a cavity therein for receiving a material that is to be finally formed into a finished piece,

a diaphragm disposed in the cavity having the material on one side thereof for forming at least one surface of the piece,

compressible fluid means in the cavity for compressing the other side of the diaphragm, means for pressurizing the fluid means so as to apply even pressure to the material, and means for establishing an electromagnetic heating field across the mold.

2. Flow molding apparatus as set forth in claim 1 wherein said fluid means comprises a liquid conductor.

3. Flow molding apparatus as set forth in claim 2 wherein said fluid means comprises mercury.

4. Flow molding apparatus as set forth in claim 1 wherein said mold is defined by at least two mold pieces forming electrodes one of said mold pieces having a cavity surface conforming in configuration to said one side of said diaphragm.

5. Flow molding apparatus as set forth in claim 4 wherein the other of said mold pieces has a cavity surface providing a reservoir between the

cavity surface and the diaphragm.

6. Flow molding apparatus as set forth in claim 1 wherein said fluid means extends along substantially the length of the material.

7. Process for molding a plastic part using a mold having a mold cavity comprising the steps of;

providing a diaphragm extending across the mold cavity,

providing a material to be molded in the cavity on one side of the diaphragm,

providing a conductive fluid means on the other side of the diaphragm,

applying pressure to the fluid means, and establishing an electromagnetic heating field across the mold to heat the material.

8. Process for molding as set forth in claim 7 wherein the field and pressure are applied concurrently.

9. Process for molding as set forth in claim 8 wherein said pressure is maintained after the field terminates.

10. Process for molding as set forth in claim 9 wherein the field is applied for a time on the order of 5 seconds and the pressure is applied for a time on the order of 10 seconds.

11. Flow molding apparatus as set forth in claim 2 wherein said fluid means comprises a metallic paste.

12. Flow molding apparatus as set forth in claim 2 wherein said liquid conductor comprises a fusible alloy.

13. Flow molding apparatus as set forth in claim 2 wherein said fluid means comprises a sodium or graphite solution.

14. Flow molding apparatus comprising; means defining a mold having a cavity therein for receiving a material that is to be finally formed into a finished piece,

a diaphragm disposed at the cavity having the material on one side thereof for forming at least one surface of the piece,

means for applying pressure to at least the diaphragm,

and means for establishing a heating field across the mold,

said mold being constructed to match said cavity configuration so as to establish heat field lines substantially perpendicular to the piece at points therealong.

15. Flow molding apparatus as set forth in claim 14 wherein said diaphragm has a uniform and constant thickness along its entire length that faces the said material.

16. Flow molding apparatus as set forth in claim 14 wherein said mold comprises a pair of electrodes having facing surfaces that extend in parallel along the length of the cavity.

17. Flow molding apparatus as set forth in claim 16 wherein the facing surfaces of the electrodes and both surfaces of said diaphragm are all in parallel along the cavity.

18. A process for molding plastics parts substantially as hereindescribed.

19. A flow molding apparatus substantially as
herein described with reference to and as shown

in any of Figures 2 to 5 of the accompanying
drawings.

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